SM22A-0227

Performance Analysis of Ring Current Models

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Abstract

Effectively modeling the high-energy particles in Earth's inner magnetosphere has the potential to improve safety in both manned and unmanned spacecraft. One model of this environment is the Fok Ring Current Model. This model can utilize as inputs both solar wind data, and empirical ionospheric electric field and magnetic field models. Alternatively, we have a procedure which allows the model to be driven by outputs for the BATS-R-US global MHD model. By using in-situ satellite data we will compare the predictive capability of this model in its original stand-alone form, to that of the model when driven by the BATS-R-US Global Magnetosphere Model. As a basis for comparison we use the April 2002 and May 2003 storms where suitable LANL geosynchronous data are available.

Model Description: Fok Ring Current

- The Fok Ring Current Model calculates the evolution of the ring current particle fluxes by solving a bounce-averaged Boltzmann transport equation
- Fluxes computed as functions of time, energy, and pitch angle
- The model uses a combined drift-diffusion approach
  - The particle drift terms include gradient-curvature drift and $E \times B$ drift (includes corotation and the ionospheric electric field)
  - The diffusion terms include radial and pitch angle diffusion
- Uses measured Solar Wind parameters to calculate radial diffusion coefficient
- The model also calculates losses due to charge exchange
- Developed at Goddard Space Flight Center by Dr. Mei-Ching Fok

Mode A: Stand Alone

- Driven by Completely Empirical Models
- Magnetic Field Inputs
  - Dipole + T96
  - IMF, SW, and DST dependent
- Electric Field Inputs
  - Weimer 2K
  - IMF and SW dependent
- Plasma sheet Inputs
  - Fok Empirical Model
  - SW dependent
- Computes H^+ fluxes over the energy range 1keV – 300keV
- Initial symmetric flux distribution employed

Mode B: MHD Driven

- Uses output from the BATS-R-US model as input
  - Ionospheric potential, Magnetic field, Density, Temperature
- BATS-R-US
  - Developed at U. Michigan
  - Solves the ideal MHD equations
  - F.A.C.s at $4R_E$ are mapped along dipole field lines to the ionosphere to calculate the electrostatic potential
- For the initial source population, the energy distribution is assumed to be a Kappa distribution
- Computes H^+ and e^- fluxes over the energy range 1keV – 300keV
- The pitch-angle distribution is assumed to be isotropic at the model's outer boundary
- "start-up" phase employed (3hrs)

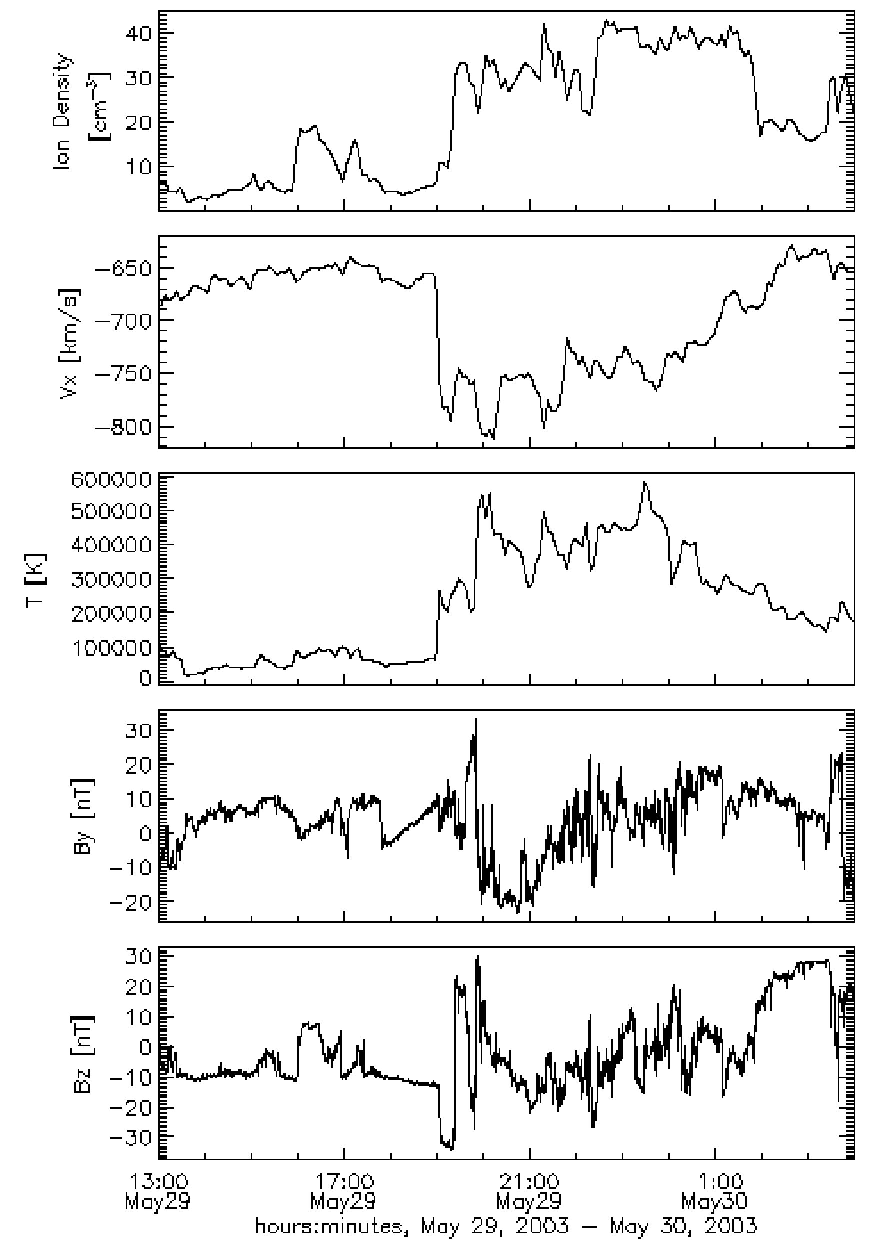
Mode C: MHD Driven - High Energy

- Computes e^- fluxes over the energy range 10keV – 5000keV
- Uses output from the BATS-R-US model as input
  - Ionospheric potential, Magnetic field
- Temperature and Density input values
  - Dayside boundary values from BATS-R-US
  - Nightside boundary values computed from measured SW
- Initial symmetric flux distribution employed

About the Plots

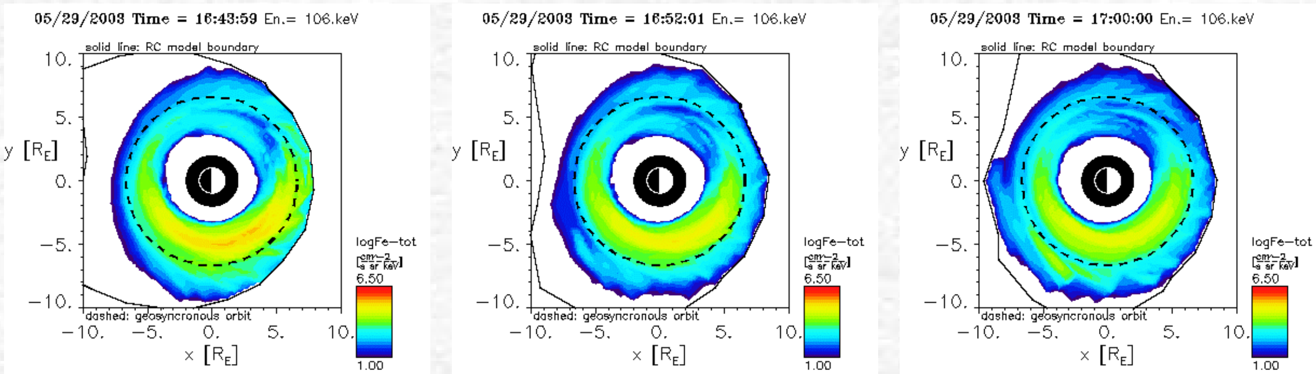
May 29-30, 2003

- Simulation Time May 29 13:00UT - May 30 4:00UT
- *At Right:* ACE spacecraft key parameter data overview plots

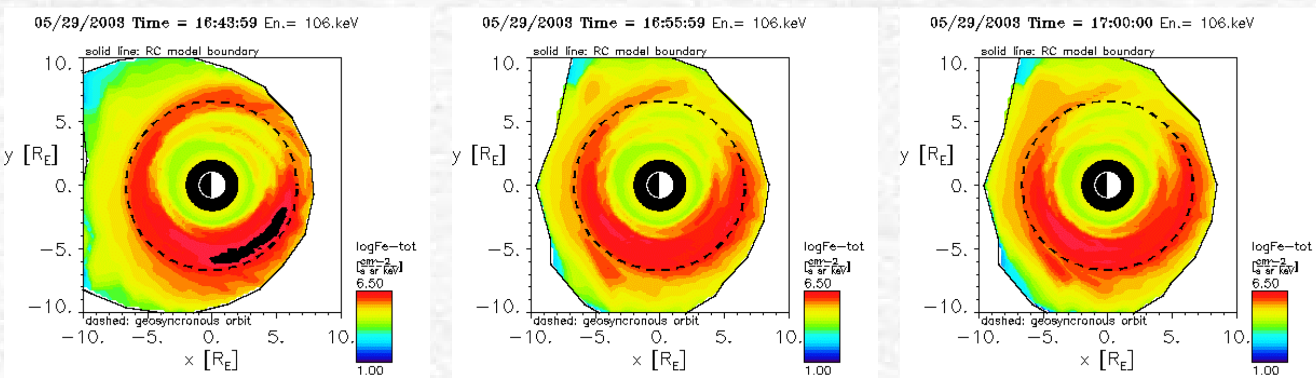


May: Injections (e$^-$)

FRC Mode B



FRC Mode C



- Timing similar but differing characteristics
- Mode C injections more spread out
  - Mode B localized near 3LT
  - Mode C injects from 20-3 LT
- Mode C has higher flux values

May: Injection Timeline (e^-)

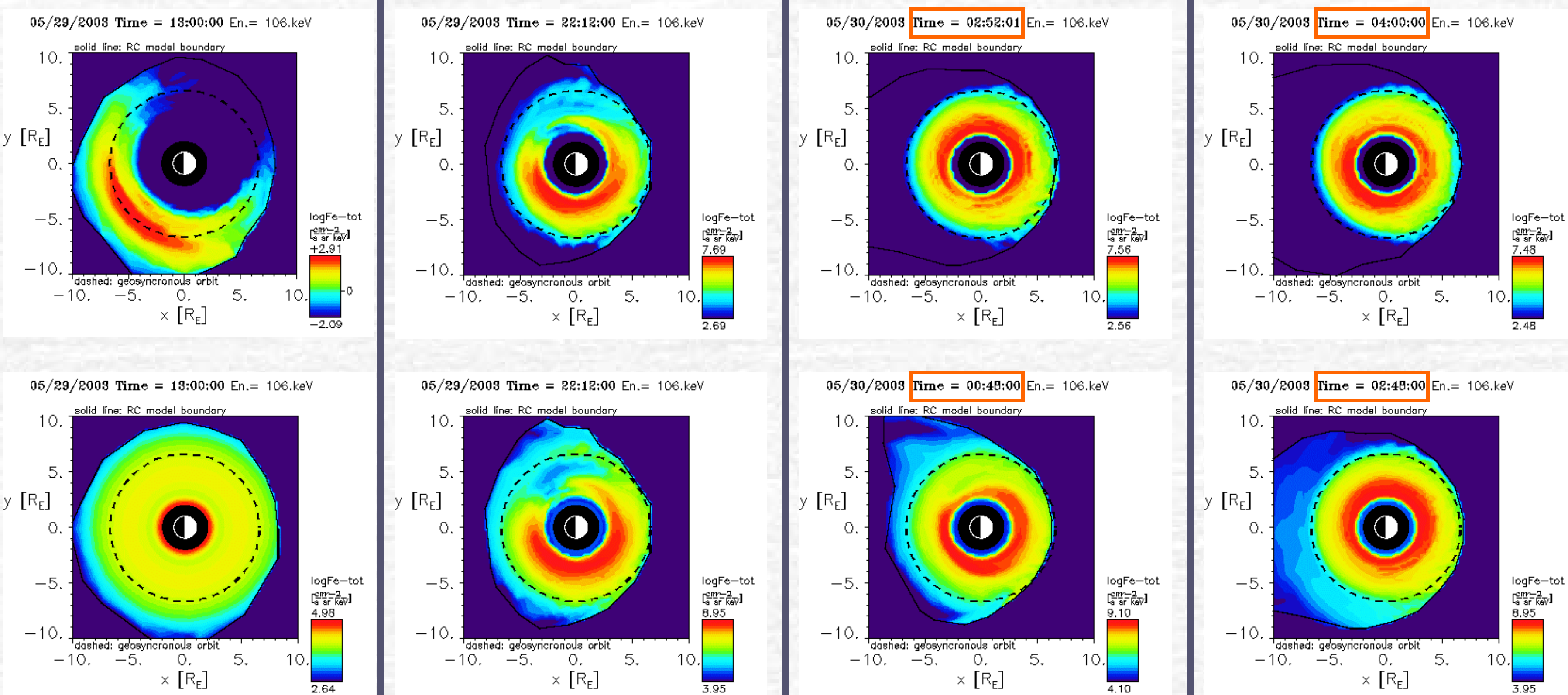
Mode B		Mode C	
Injection Start	Location (LT)	Injection Start	Location (LT)
15:12	2 – 4	15:52	0 – 6
16:52	3	16:48	20 – 3
18:28	1 – 3	18:31	2 – 4
20:16	0 – 4	20:00	2 – 4
20:36	23	20:16	0 – 4
20:52	3	20:36	22 – 3
21:24	1 – 3	20:48	0 – 3
23:28	23 – 1	23:28	23 – 1
23:40	2 – 6	23:40	1 – 6
00:04	21 – 24	00:04	21 – 24
00:24	1 – 4	00:19	1 – 4

May: Symmetry (e^-)

Simulation Start	Consistent Asymmetry	Symmetric RC Start	Fully Symmetric

B

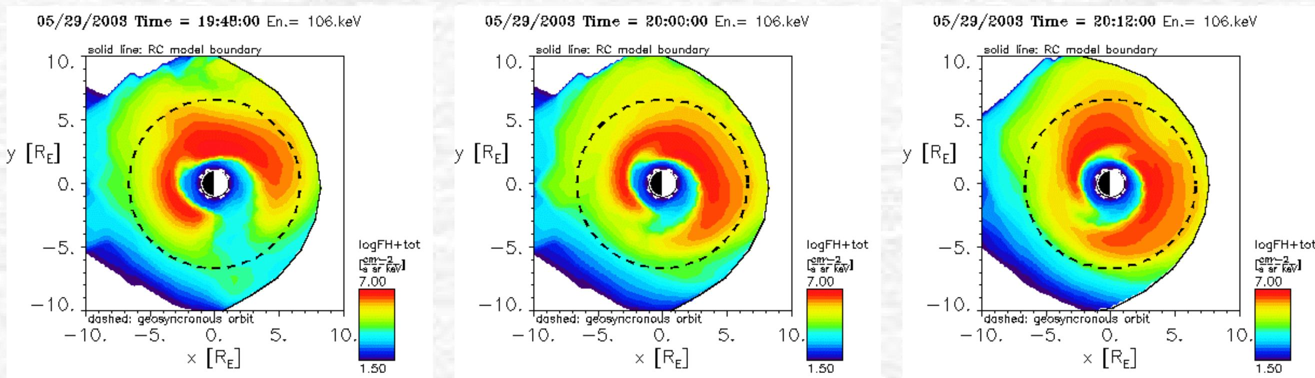
C



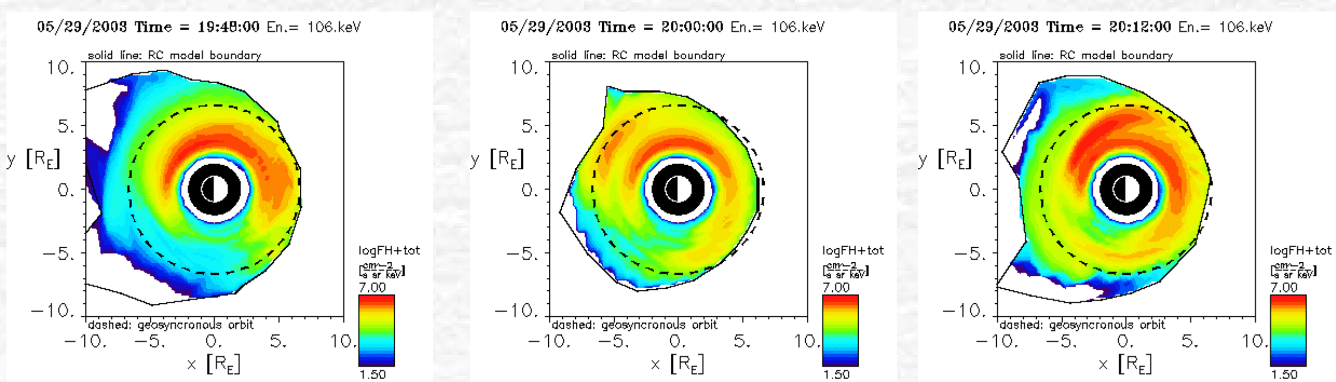
May: Injections (H^+)

- Distinct injections seen in Mode B
- No clear injections in Mode A simulation

FRC Mode A



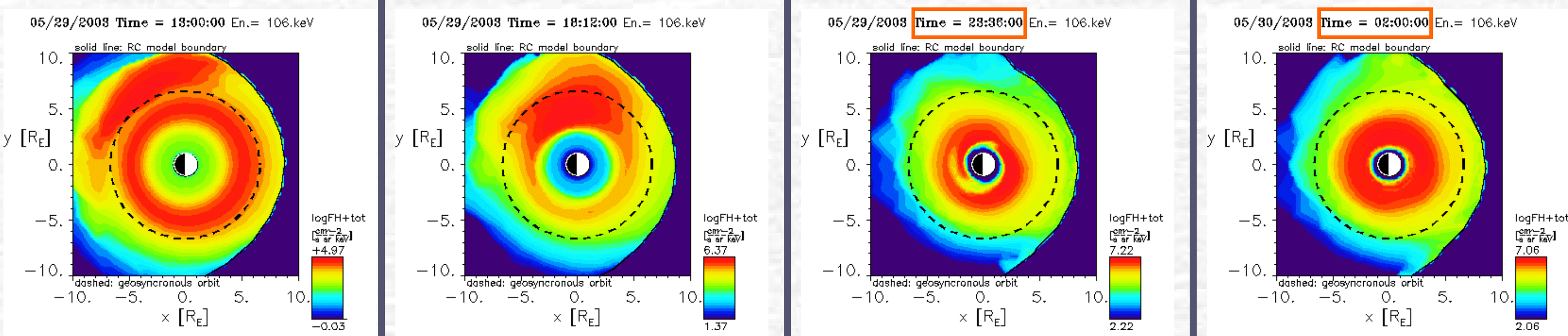
FRC Mode B



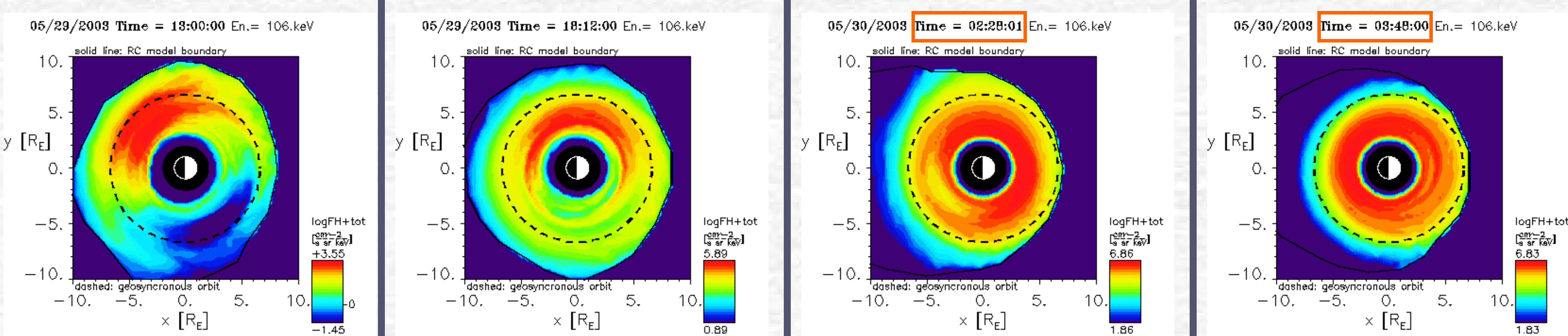
May: Symmetry (H^+)

Simulation Start	Consistent Asymmetry	Symmetric RC Start	Fully Symmetric

A



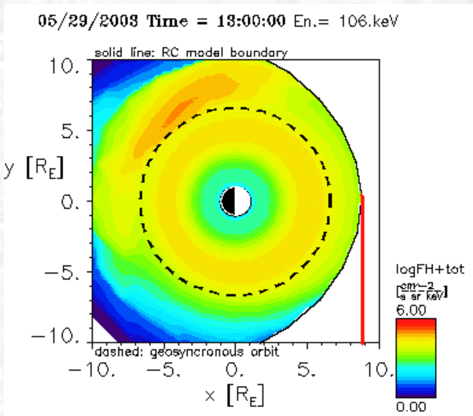
B

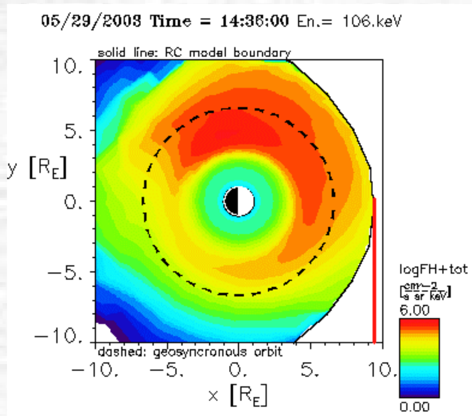


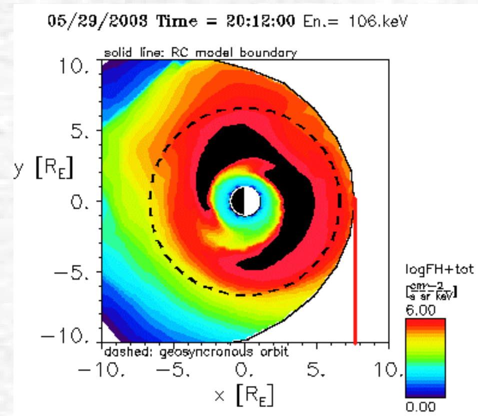
May: Magnetopause (H^+)

Start Max Min

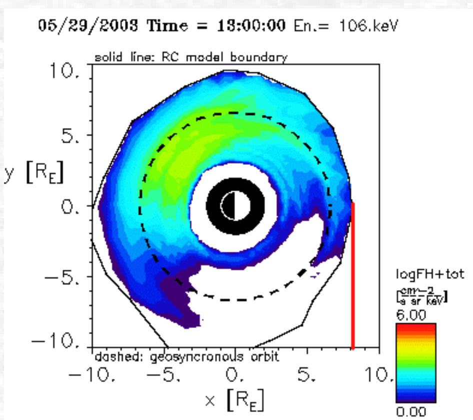
A

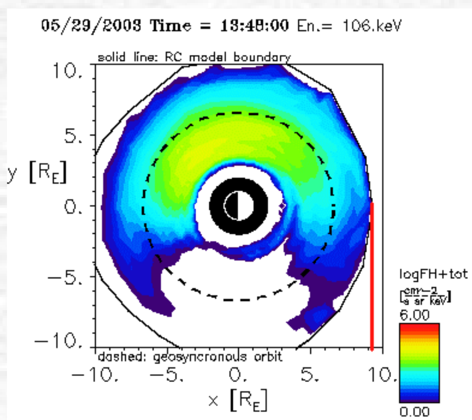


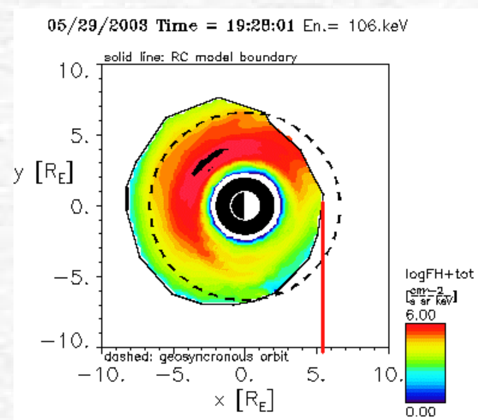




B





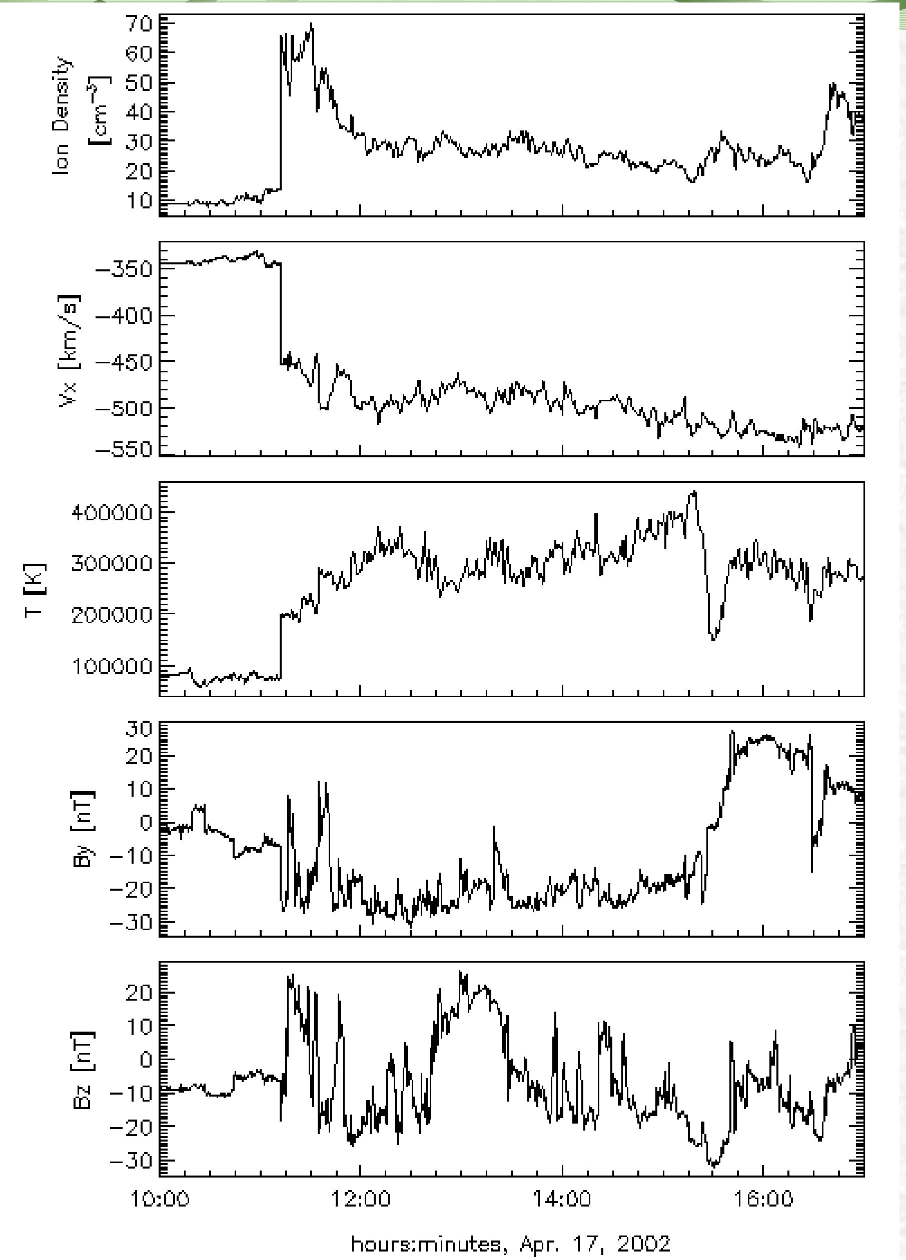


May: Discussion

- Particle Injections
  - (e^-) Modes B and C tend to see injections at nearly the same times. Small variations in timing are observed. Often these injections are similar in spatial size, however, there are cases in which the Mode C injections are clearly spread over a wider area. Flux magnitude in Mode B is much smaller than in Mode C.
  - (H^+) Modes A and B differ significantly. Mode A never sees any distinct particle injections, with only gradual increases in particle flux throughout the simulation. Mode B proton injections occur with the frequency and size seen in the Mode B electron simulation. Fluxes in Mode B, again, tend to be smaller.
- Symmetry
  - The Mode B simulation keeps an asymmetric ring current longer than either the Mode A or C simulations (2–3 hours). Mode A sees a symmetric ring current approximately 1 hour earlier than Mode C.
- Magnetopause Location
  - Magnetopause location in Modes B and C are nearly identical. Mode A has less extreme variations in magnetopause location. Movement of the magnetopause in all models were similar, reaching maximum and minimum distance near the same simulation times.

April 17, 2002

- Simulation Time 10:00UT - 17:00UT
- *At Right:* ACE spacecraft Level 2 data overview plots



Conclusions

- Mode B vs. Mode C
  - The higher flux seen in Mode C is most likely due to the initial particle distribution. Mode B computes its initial distribution from MHD calculated temperatures and densities, giving lower initial values.
  - Nightside boundary differences are the most likely the cause of the wider-spread injections seen in Mode C.
- Mode A vs. Mode B
  - The more distinct particle injections seen in Mode B is due to the MHD magnetic and electric fields being more dynamic than the empirical models.
  - The magnetopause boundary in Mode B comes within geosynchronous orbit on several occasions

References

- Fok M.-C., T. E. Moore, and M. E. Greenspan, Ring current development during storm main phase, *J. Geophys. Res., 101,* 15,311-15,322, 1996.
- Fok M.-C., and T. E. Moore, Ring current modeling in a realistic magnetic field configuration, *Geophys. Res. Lett., 24,1775-1778*, 1997.
- Powell K. G., P. L. Roe, T. J. Linde, T. I. Gombosi, and D. L. De Zeeuw, A solution-adaptive upwind scheme for ideal magnetohydrodynamics, *J. Comput. Phys*., 154(2), 284-309, 1999.

Acknowledgments

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